Mars Exploration Rover Project

Mars Global Surveyor - Mars Exploration Rover Relay Link Interface Control Document

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Mars Global Surveyor - Mars Exploration Rover Relay Link Interface Control Document

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Revision & DATE	**Change Description**	**Pages added**	**Pages Deleted**	**Pages Modified**
2/4/02	Initial Release			
2/8/02	Redlines to the Initial Release. Page 4: MGS mode configuration, Page 11: Playback rates, and Other editorial updates.			8
2/12/02	Redline to Redline copy Remove UHF TLCM from figure 4-1. Editorial updates			5
2/22/02	Signature Page Add the MER-MGS MOA to the reference document Re-word Section 2.2.1, Section 5 Add footnote to denote the units of x-y axis for Figure 3-2 and 3-2 Add MER latency requirements in Section 5 Updates in section 8 to clarify the phasing requirements and correct typos. Add Section 8.3.4 to provide feedback from MER to MGS. Add surface relay duration statement to Section 8.4 Specify required MSSS support to end-to-end test Correct acronyms for MOC and TDS			9
4/10/02	Add Mars Program Office signatory Add EDL playback policy in Section 8.3 Specify the Navigation information transfer format in Section 8.1 (5). Specify the Stanford Test in 2003 as a goal and require MCR by September 2002 Clarify the 2 hours response time from MSSS is the technical support in Section 8.4.4			
10/10/02	1. Update signature page 2. Incorporated redlines on Sections 8.1 – 8.3 from the signed initial release version			5

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1. Introduction

1.1 Scope

This document specifies the interface for the transfer of data between the Mars Exploration Rovers (MER) and the Mars Global Surveyor (MGS), allowing MGS to serve as a communication relay during the MER-A/MER-B Entry-Descent-Landing (EDL) and rovers surface operations on the Mars surface.

1.2 Reference Documents

- Packet Telemetry, CCSDS-102.0-B-5, November, 2000.
- JPL D-20451, MER 420-9-152 – Mars Exploration Rover and Mars Global Surveyor Memorandum of Agreement
- JPL D-14514, Mars 96, Data Processing of Mars Relays - Interface Manual
- JPL D-14572, Mars 96, Data Processing of Mars Relays - Requirements Specification and Software Specification.
- Mars'96 Mission - Mars Relay - Lander Polling and Data collection Principles, CNES N 011/CT/AE/TT/TS, Feb-95
- Mars'96 Mission - Link Budget Updating using the Mars Relay on MGS, CNES DT-96-014-CT/AE/TT/TS, March-96
- MGDS User's Guide, Volume 2: Working with File Data MGSO0088-00-11-02 (D-6060), August 1997, Part V: Distributed Object Manager.

2. Physical and Data Layer Description

The MGS has a single string UHF subsystem (referred to as Mars Relay, MR) consisting of a transceiver, diplexer and a quadrifilar helix antenna. Transfer of data is possible only on the return link (surface element to orbiter), but the forward link is necessary to operate the link in the MBR (Mars Balloon Relay) protocol mode as described below (MER will use this mode during surface operations). It's possible (ref. Sec 2.2) to have a surface element continuously transmit; ignoring the MBR protocol. However, while this ensures continuous MER transmissions by eliminating the need for handshaking, it will cause MR to lose approximately 1 second of MER data out of each 16 seconds transmitted. (MER will operate in this mode during EDL).

2.1 Surface Communications

2.1.1 MGS MBR Protocol

The MBR protocol is employed by MGS's Mars Relay (MR) subsystem to relay telemetry received from MBR-compatible Mars surface element(s) back to Earth. MBR protocol does not support relay of command data to surface transceivers. MER will make use of the MBR protocol during its surface operations.

The MBR protocol is based on the use of a calling sequence, named BTTS (Balloon Telemetry Time Slot), shown in Figure 2-1. The sequence is 16 seconds long and is continually transmitted by the MR on MGS.

Until a surface element responds, the transmission consists of 14 seconds of a 437.1 MHz beacon carrier frequency modulated (df=±4000Hz) with one of three Request Command (RC) subcarriers, RC1 through RC3, followed by 2 seconds of unmodulated carrier. Each surface element must respond to only one of the RC frequencies. RC1 is used to address both MER A and B, with a subcarrier frequency of 1484 Hz.

When the MER transceiver detects the RC1 subcarrier, it will respond at 401.528711 MHz with the transmission of 1.2 seconds of pure carrier (or CW, Continuous Wave) followed by a repeating 511 bit PN sequence[1]. If the return link is strong enough to allow the MR receiver to lock on the carrier and then on the data, the MR transmission will switch from the RC1 subcarrier to TC (Transmit Request) -having a subcarrier frequency of 1376 Hz. Once MER detects the TC subcarrier - it will complete - the PN transmission cycle in progress and then transmit data from - its transceiver buffer. If at any moment the MR detects unacceptable return link -degradadation (a BER greater than 1E-2), MR will switch to transmit CW until the end of the 16-second BTTS cycle, then the BTTS cycle will start again with transmission of the RC1 subcarrier signal.

If link quality is good, the MR transmitter will switch to CW at 15 seconds into the BTTS cycle; this period is used in the transceiver to introduce its housekeeping telemetry (HKTM) in the data flow to the Mars Orbiter Camera (MOC), which buffers the MR data. Note: MGS returns MER data to earth in the same bit pattern as it was received from the surface element(s). MGS does not perform error detection or correction on the surface-to-orbiter data.

[1] The PN sequence is designed to help bit and Viterbi synch; the MGS MR receiver is designed to lock up in less than 4000 bits

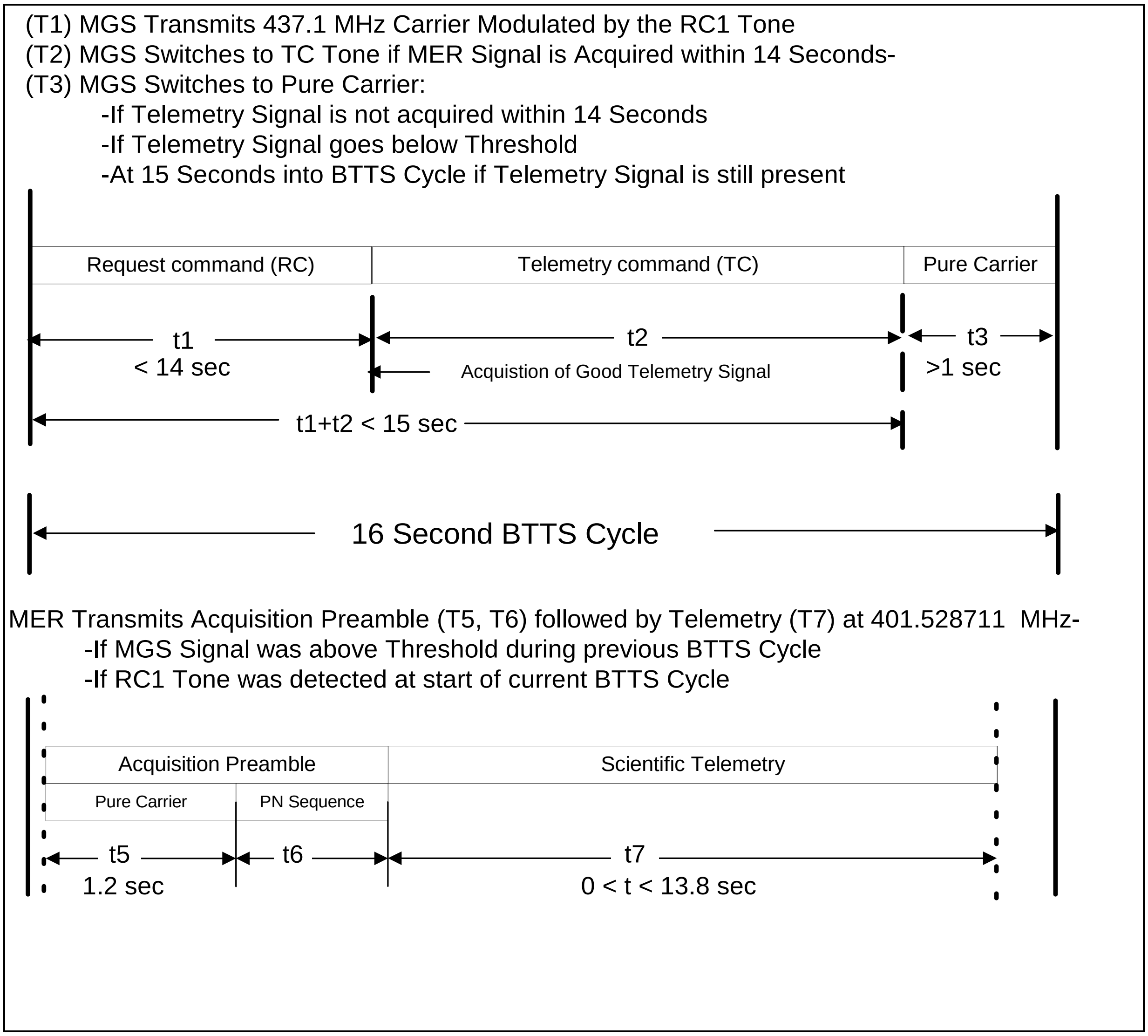


Figure 2-1 BTTS Timeline

Typically when the BER is low, transmission time is limited between 13.3-13.8 seconds out of 16 seconds; so the resulting efficiency of the protocol is approximately 83-86%.

2.1.2 Relay Modes

During relay sessions with MER, MGS will be in one of 2 modes:

1. Mode 1 is defined by RC1 tone, return frequency of 401.528711 MHz, Viterbi decoder ON and a data rate of 8 kbps
2. Mode 14 is defined as above but with a data rate of 128 kbps

The MER transceiver will be configured by avionics in the following corresponding modes:

1. RX = (MGS MR, 8 kbps, FSK, BY-PASS COD); TX = (MGS MR, 8 kbps, PSK, CONV_VIT_G2_inv);

2. RX = (MGS MR, 8 kbps, FSK, BY-PASS COD); TX = (MGS MR, 128 kbps, PSK, CONV_VIT_G2_inv);

2.2 EDL Communications

2.2.1 MER's "1-way mode" (aka EDL mode)

During EDL, the relay link SNR will be too low for MER to reliably detect MGS-MR's TC and RC1 tones. In this phase the MER transceiver will be configured to continuously transmit to MR at 8 kbps. Since MER transmission is continuous and MR doesn't acquire transmitted data during its one-second HKTM collection and transfer to MOC, some MER data will be lost. The radio will maintain lock during this period.

However, MER data may be lost for moments when, due to low SNR, MR loses bit-sync and Viterbi code lock. There may also be moments when MER avionics cannot keep MER's transceiver buffer from going empty. In this situation, MER's transceiver will insert the MBR protocol 511-bit PN sequence as an aid to maintaining bit sync and code lock.

2.2.2 EDL Communications modes and configurations

During EDL relay sessions with MER, MGS S/C will be configured in the following mode:

1. Mode 1 is defined by RC1 tone, return frequency of 401.528711 MHz, Viterbi decoder ON and a data rate of 8 kbps
2. MR transmitter shall be powered ON and ENABLED, and configured for "MR Mode 1" as defined above.
3. MOC shall be ON; configured and sequenced to collect only data from the MR. MOC "autonomous Reboot" capability shall be configured and timed to further minimize probability of MER EDL data acquisition and return losses.
4. MGS shall be configured (if feasible) to simultaneously return MOC packets in SE-1 or SE-2 real-time modes, and record the data for later playback.

During EDL relay sessions with MGS, MER’s transceiver will be configured by avionics in the following mode:

1. RX = (MGS MR, 8 kbps, FSK, BY-PASS COD); TX = (UNRELIABLE, 8 kbps, PSK, CONV_VIT_G2_inv);

3 Relay Link Performance

3.1 MER

- All parameters are specified at the common port of the diplexer
- RF Power > 39.0 dBm
- Receive Threshold < -118 dBm (TC and RC tones) at ±6 kHz
- Circuit Loss = 0.6 dB (TBC, between antenna and diplexer)
- Antenna Gain: two antennas are present, both are monopole linearly polarized- see figures for preliminary pattern measured on mock-ups of the spacecraft.

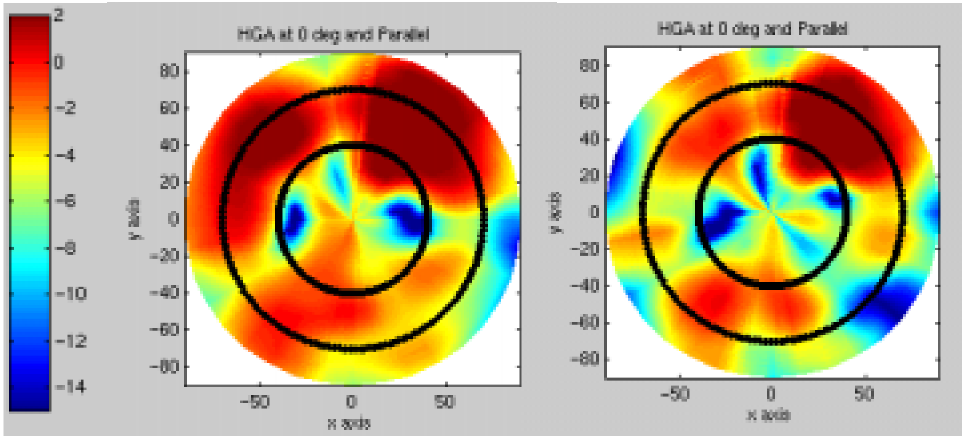


Figure 3-1. MER Rover Antenna Pattern (in dBic at 401 and 437 MHz)[2]

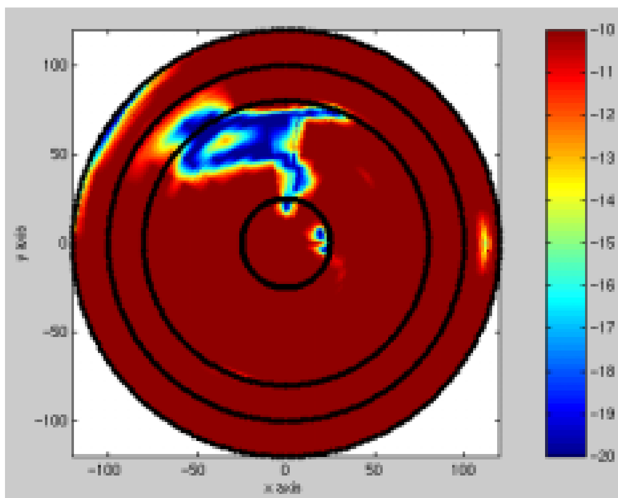


Figure 3-2. MER Lander Antenna Pattern (in dBic at 401 MHz)[3]

3.2 MGS

- All parameters are specified at the transceiver input and output ports
- RF Power = 1.1 W
- Receive Threshold < -125 dBm (8 kbps coded, BER=1E-3) and < -114.5 dBm (128 kbps coded, BER=1E-3)
- Carrier Acquisition <-125 dBm; ±23 kHz from center frequency
- Circuit Loss = 1.0 dB
- Antenna Polarization: Right Hand Circular

[2] X & Y axis are in the unit of degrees
[3] X & Y axis are in the unit of degrees

- Antenna Gain: see Figure below for antenna gain (worst case for all the azimuth cuts measured)
- Antenna Axial Ratio: < 4 dB at 401 MHz, <5.5 dB at 437 MHz

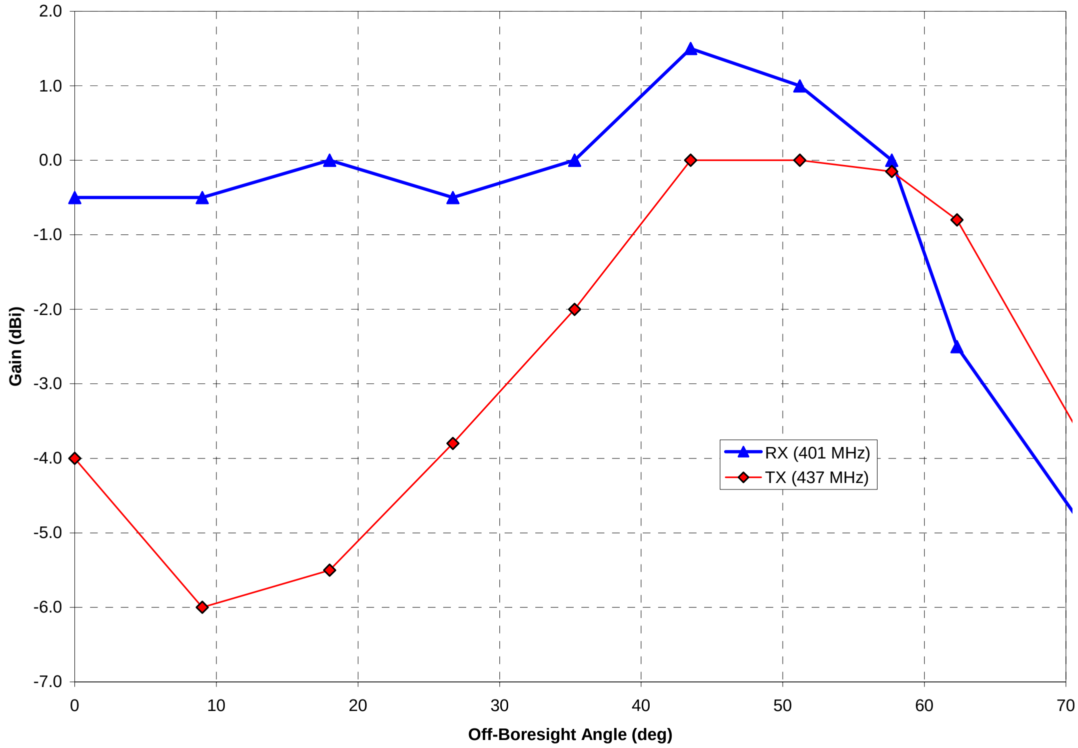


Figure 3-3. MGS UHF Antenna Gain vs. Off-Boresight Angle

4. END TO END DATA SYSTEM

4.1 End-to-End Data Flow

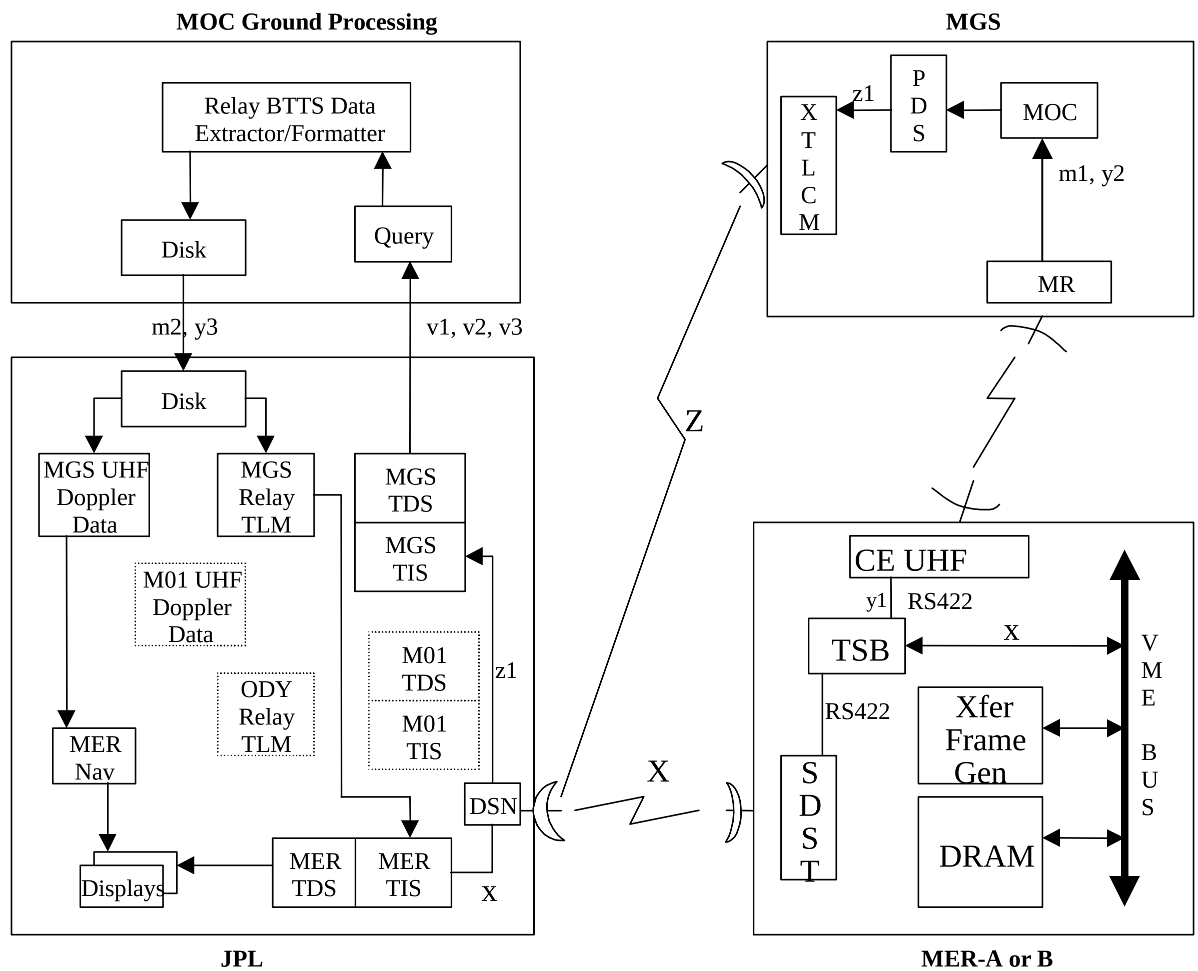


Figure 4-1 End-to-end system

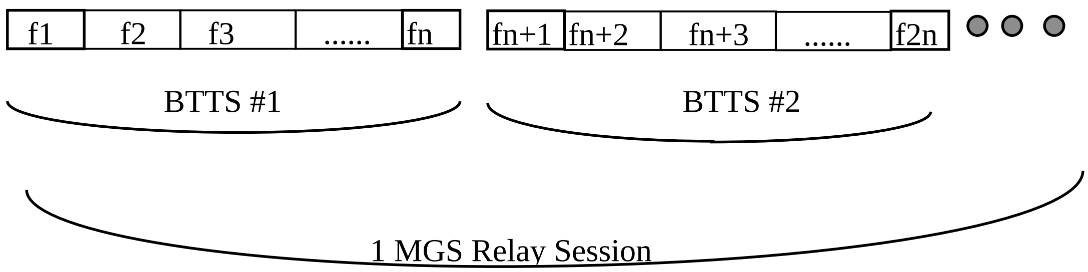
Figure 4-1 describes a high level end to end data flow. The definition of the data flow in the figure is defined as follows.

1. x: a continuous stream of transfer frames. MGS should treat it as a contiguous bit stream. f stands for transfer frames.

f1	f2	f3	f4	....	fn	fn+1	....

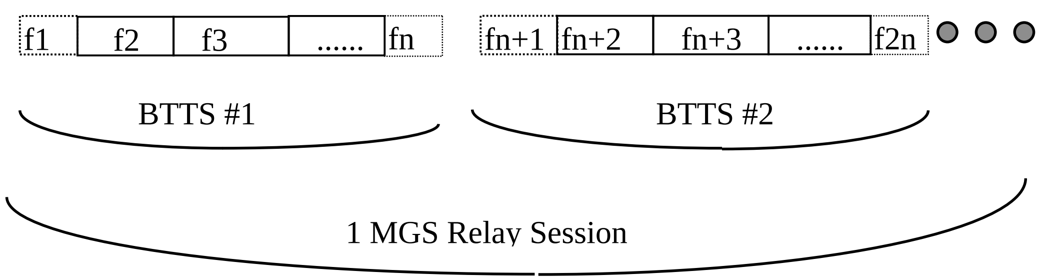
2. X: MER X-Band DTE. X is not covered in this ICD.

3. y1: a contiguous stream of frames routed to MER's UHF radio for relay through MGS. During EDL, MER uses the one-way mode and transmits data without listening for MGS. For surface Operation, - MER operates in MBR (i.e. two-way -) mode; recall no deterministic data loss - occurs in MBR mode.



4. m1: m1 represents MR's engineering "housekeeping" data (including Doppler information) transferred to MOC at the end of each BTTS. The unit of m1 is called HKTM. m1 and y2 (defined in item #5) form a bitstream that MR sends to MOC.

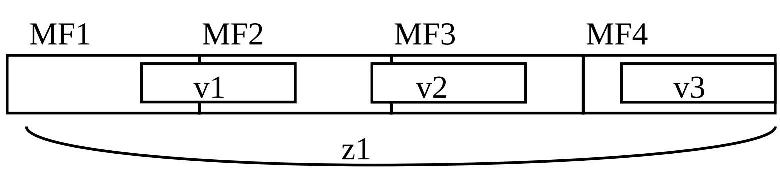
5. y2: y2 is the y1 received by MOC. y2 has the same definition of y1 except that it may contain bit dropouts, errors, and partial bitstream duplications resulting from MGS and MER relay via MBR protocol at periods/points of poor link SNR. . The following diagram shows only a fraction of the first transfer frame. Please note that both the front end and back end of a BTTS may have data losses. These ends are represented by the dotted boxes.



6. z1: the MGS transfer frames that contains MOC packets which contain m1 and y2 .

7. Z: Z is the downlink data sent from MGS S/C to the DSN ground antenna.

8. v1, v2, v3 are MOC packets.



MF1 thru 4: MGS Transfer Frames
v1 thru 3: MOC packets embedded in MGS transfer frame

9. y3: y3 are files consisting of GIF blocks (in SFDU format), each file contains all the MER data received at MR in a relay session.

10. m2: m2 represents HKTM and summary information generated by MSSS after processing the relay stream.

4.2 MER Flight System

Onboard MER, the transfer frame formatting depends on the UHF mode to be used. There are two UHF modes to be used for the MGS relay operation: (1) One-way Mode, and (2) MGS Mode.

4.2.1 MER's "One-way Mode" (aka. EDL mode)

The One-way mode is used for the UHF relay during EDL. In this mode, the 1760-bit transfer frame is used. The transfer frames are checksummed and a sync marker is placed at the front of each frame by the flight software, see Figure 4-2. The data bypass the telecom board R-S function and are put in the UHF transceiver's Transmit FIFO buffer. The UHF transceiver pulls the data bits from the Transmit FIFO buffer and sends the raw data bit stream to MGS continuously, bypassing the proximity-1 transfer frame header and CRC generation. No handshaking is performed with this mode.

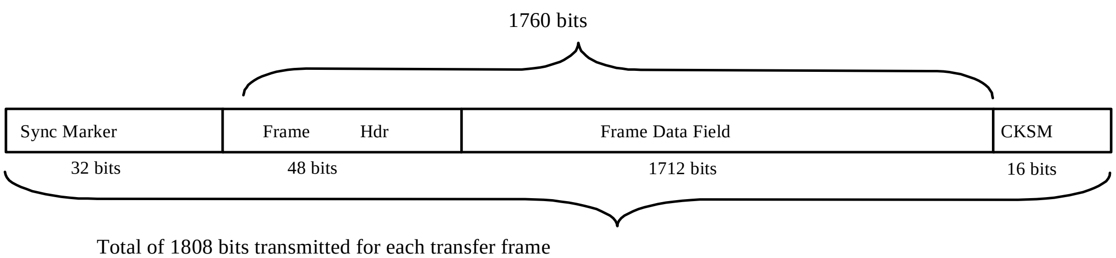


Figure 4-2 MER Transfer Frame Used in One-way Mode

4.2.2 MER's "MGS Mode"

MER's "MGS Mode", unlike "1-Way Mode", includes full implementation of the MBR protocol. Since adequate link margin is expected, MER will employ "MGS mode" during surface operations._In MGS mode, an 8800-bit transfer frame is used. The transfer frames are Reed-Solomon encoded and a sync marker is placed at the front of each frame, see Figure 4-3. The resulting data are then written to the UHF transceiver's Transmit buffer. The UHF transceiver reads data bits from the Transmit buffer and transmits the data stream to MGS, bypassing the proximity-1 header and CRC.

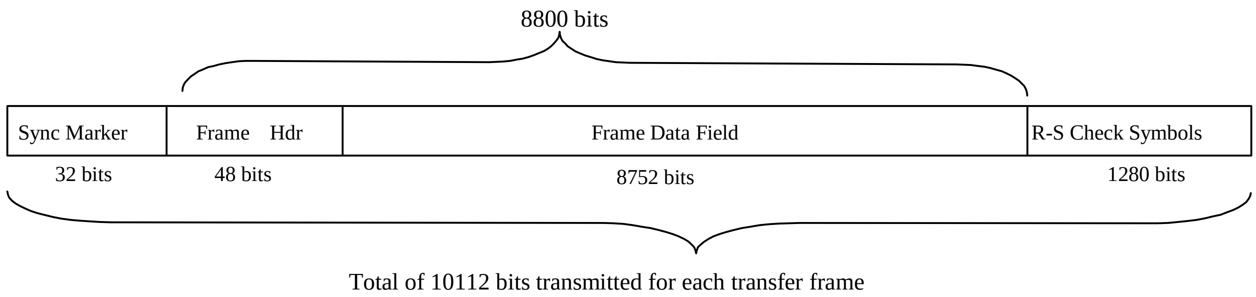


Figure 4-3 MER Transfer Frame Used in Unreliable Bit Stream Mode

4.3 MGS Flight System

MGS onboard data system is shown in figure 4-4. The MOC (Mars Orbiter Camera) instrument captures the MR data and stores them in MOC's buffer.

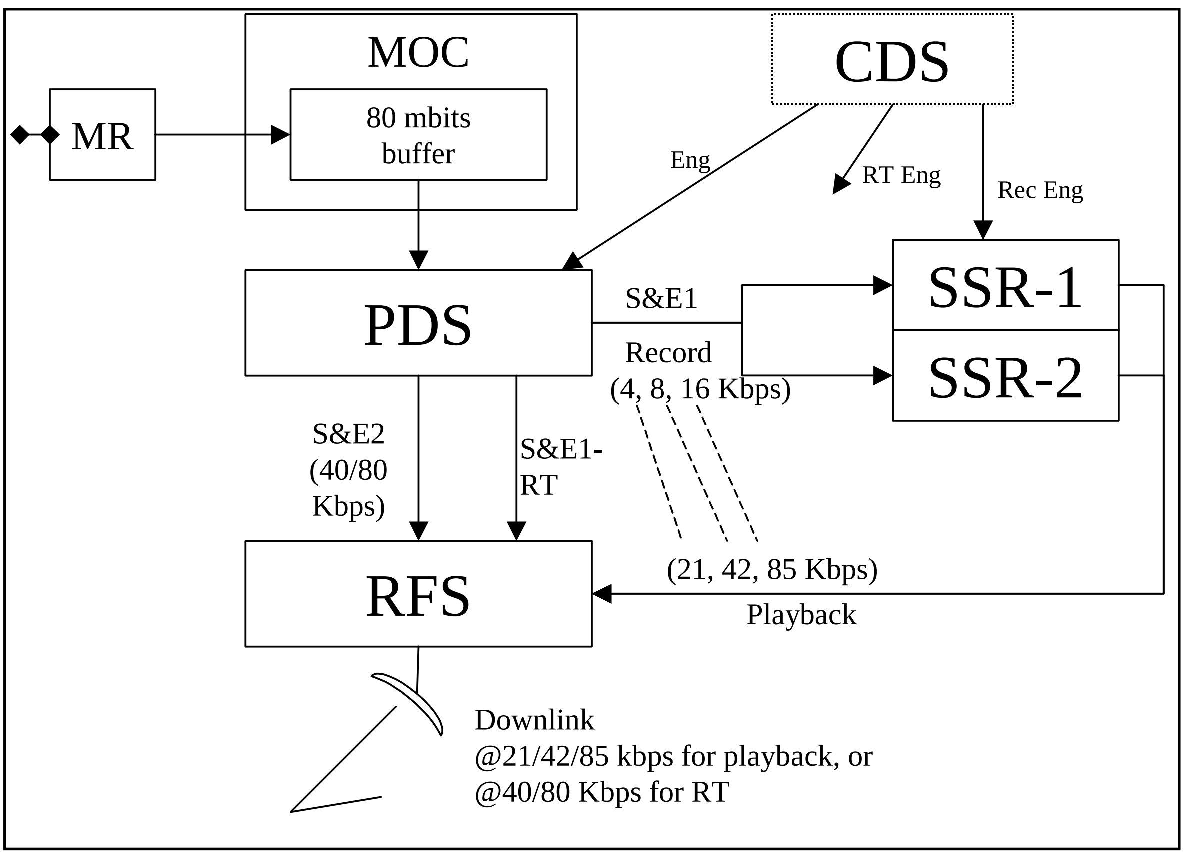


Figure 4-4 MGS On Board data system

MOC's buffer consists of 40 memory segments of 256 Kbytes each (with 16 Kbytes of overhead). The data captured and stored in the MOC buffer are returned either when a memory segment is complete or when the MR reception period has expired. The MOC engineering telemetry reports buffer usage at high telemetry rates (as was used in support of the DS-2 and MPL searches). This information is returned before the data collection is complete, which provides indication whether or not relay data are being collected. The data from the MOC buffer is sent to the PDS for packetizing. It is then either recorded to the SSR or downlink to Earth, depending on which mode is selected. Note: Simultaneous recording and real-time downlink is configurable, if desired.

MGS has three data handling modes:

(1) Science and Engineering 1 (S&E1) – data are recorded to the Solid State Recorders (SSRs) and are played back later during DSN passes.

(2) Science and Engineering 2 (S&E2) – data are transmitted to Earth in realtime.

(3) Science and Engineering 1 + Realtime (S&E1-RT) – data are transmitted to Earth in realtime and simultaneously recorded onto SSRs in S&E1 format for playing back during later DSN passes.

The data recording and playback rates are matched to allow 24 hours of continuous mapping data to be recorded and played back the next day during the DSN pass.

Record Rate	Playback Rate
4 kbps	21.333 kbps
8 kbps	42.667 kbps
16 kbps	85.333 kbps

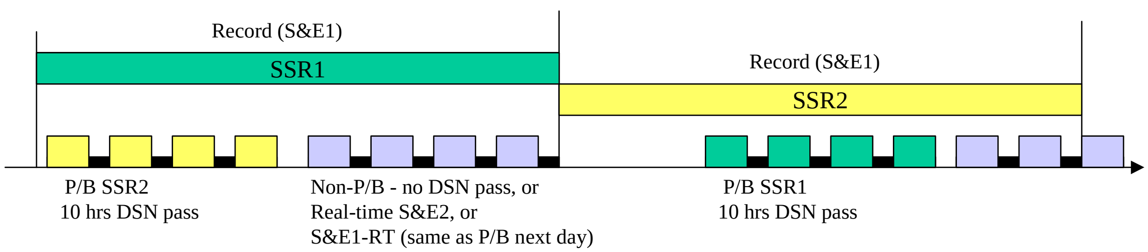


Figure 4-5 MGS mapping operation

Figure 4-5 illustrates the MGS’s routine mapping operations. The data recorded to one segment of an SSR will be played back the next day. During the playback of one SSR segment, mapping data are simultaneously recording onto a second SSR segment.

In MGS "nominal mapping operations", if a UHF pass occurs in the beginning of the mapping cycle, it will not be played back until the next day’s DSN pass. Therefore, latency of MER data's return to earth may exceed 24 hours from the time it was received by MGS. Reducing the worst-case latency would require non-standard (i.e. custom) MGS sequence builds. Establishment of -requirements for custom MGS sequence builds occurs via approval by the Multi-Mission Office (MMO) Mission - Change Control Board (MCCB).

4.4 MGS Ground Data System

4.4.1 MGS Telemetry Processing

MGS uses the DSN and MMO ground data system for the telemetry data acquisition and processing. The MGS TIS performs the telemetry transfer frame synchronization, Reed-Solomon decoding, and packet extraction. The resulting MOC packets containing the relay data are stored in the MGS TDS, which is available for further processing by MSSS.

4.4.2 MSSS Processing

MSSS is responsible for extracting the - MR data from the MOC packets. The relay data are SFDU formatted and delivered to the DSMS server. The detail interface definition is specified in section 6. In general, MSSS performs the following functions.

- query the MOC packets,
- extract the embedded relay data (called BTTS data) and HKTMs,
- format the BTTS data in SFDU defined in Section 6.3 -- File Formats and File Sizes,
- deliver the BTTS and HKTM files to the DOM server with file transfer tools.

4.5 MER Ground Data System

- Relay telemetry processing software, as part of the MER telemetry ground processing, retrieves the BTTS file from DOM. The BTTS file is input to the MER TIS for frame synchronization. Depending on the type of transfer frame contained in the relay packets, either Reed-Solomon or checksum decoding is performed. The valid transfer frames are then further processed for packet extraction and channelization as necessary. The resulting products are stored in the MER TDS with label clearly identifying the source and relay path.

5. END TO END PERFORMANCE

The data latency requirement for EDL relay is 15 minutes from the time data hit the ground to the time they are available for MER Telemetry processing.

The data latency requirement for surface relay is 36 hours from the time data is received at the MR radio to the time they are available for MER ground data system. In case of emergency, the latency is required to be changed to 6 hours. This can be done by uploading a special MGS sequence and interrupting the current sequence. The emergency condition will be coordinated at the project manager's level. When this latency change is necessary, the turn around time is 4 to 5 days.

The relay data latency performance described below is for reference only. It provides a general concept of where the time delay occurs and how to account for those delays. It is not to levy the latency requirements on any element. Although the actual delay may vary, it is expected that 95% will fall within the estimated performance.

5.1 EDL

The following chart is an end-to-end performance summary of the data systems for the EDL relay. The following items are assumptions made in the performance summary:

1. The data rate between the MER and MGS is assumed to be 8 Kbits per second for EDL.
2. The EDL relay session is assumed to be approximately 10 minutes in duration.
3. A 10-minute relay session contains approximately 38 BTTS.
4. 38 BTTS (15 seconds each) have a data volume of 4.56 Mbits (8k x 15 seconds x 38 BTTS).
5. 4.56 Mbits (plus 15% header overhead) will take 130 seconds to be transmitted (at 40 Kbps down link rate) from the MGS X-band Antenna to the DSN station.
6. The NASCOM bandwidth between MMO and MSSS is 672 Kbits/second, with an efficiency rate of 80%. The effective throughput is 537 Kbits/seconds
7. MOC packet length = 150 bytes SFDU header + 1080 MOC header & data = 1230 bytes. 150/1080= 14% SFDU Overhead
8. Total Data Transfer Time from MGS TDS to MSSS = 2640 Kbits x 1.15/537 = 5.7 seconds, if the MOC packet processing is at MSSS.

Table 1 – EDL Relay End-to-End Data System Performance Estimation

	FROM	TO	Time Estimates	Comment

	FROM	TO	Time Estimates	Comment
1	MGS MR UHF Link Receiver	DSN Antenna	1. 10 min 2. 9 to11 min 3. 2.2 min	The time estimates in this row include 1. UHF Communication time 2. One way light time ~9 min for MER-A and ~11 min for MER-B 4. RF Transfer Time from MGS to DSN Antenna The time estimate assumes the relay time downlink during EDL
2	DSN Antenna	MGS TDS	1. 3 min 2. 2 min	The time estimation in this row includes: 1. DSN Antenna to JPL GIF 2. GIF to TDS
3	MGS TDS	MSSS	1. 5.7 seconds 2. 5 min	The time estimation in this row includes: 1. data transfer from MGS TDS to MSSS 2. MSSS Processing Time
4	MSSS	File Server	1. 1.5 min	The time estimation in this row includes: 1. data transfer from MSSS to MMO file server via FTP.
5	File Server	MER TDS	1. 1.5 min	The time estimation in this row includes: 1. retrieves data from the file server, processes at TIS and loads into TDS.
6	MGS MR UHF Link Receiver	MER TDS	34.2 to 36.2 Minutes	Total latency

5.2 Surface Relay

The following chart is an end-to-end performance summary of the data systems. The following items are assumptions made in the performance summary:

1. The data rate between the MER and MGS is assumed to be 128 Kbps during the surface operations.
2. Each relay session is assumed to be approximately 6 minutes in duration.
3. A 6-minute relay session contains approximately 22 BTTS.

4. 22 BTTS (15 seconds each) have a data volume of 42.24 Mbits (128k x 15 seconds x 22 BTTS) for surface operations.
5. 42.24 Mbits will take 1214 seconds (~20 minutes) to be transmitted (at 40 Kbps down link rate) from the MGS X-band Antenna to the DSN station.
6. The NASCOM bandwidth between MMO and MSSS is 672 Kbits/second, with an efficiency rate of 80%. The effective throughput is 537 Kbits/seconds
7. MOC packet length = 150 bytes SFDU header + 1080 MOC header & data = 1230 bytes. 150/1080= 14% SFDU Overhead
8. Total Data Transfer Time for MER Surface Operation between MGS TDS and MSSS = 42240 Kbits x 1.15 / 537=90.46 seconds.

Table 2 – Surface Relay End-to-End Data System Performance Estimation

	FROM	TO	Time Estimates	Comment
1	MGS MR UHF Link Receiver	DSN Antenna	1. 6 min 2. 5 min 3. 10 to 18 min 4. 20 min	The time estimates in this row include 1. UHF Communication time 2. DSN Lockup time - 5 min 3. One way light time - 10 min at the EDL to 18 min at EOM 4. RF Transfer Time from MGS to DSN Antenna The time estimate does not include the time delay caused by the buffering scheme of the MOC on board.
2	DSN Antenna	MGS TDS	1. 3 min 2. 2 min	The time estimation in this row includes: 1. DSN Antenna to JPL GIF 2. GIF to TDS
3	MGS TDS	MSSS	1. 2 minutes 2. 5 min	The time estimation in this row includes: 1. data transfer from MGS TDS to MSSS 2. MSSS Processing Time
4	MSSS	File Server	1. 1.5 min	The time estimation in this row includes: 1. data transfer from MSSS to MMO file server via FTP.
5	File Server	MER TDS	1. 1.5 min	The time estimation in this row includes: 1. retrieves data from the file server, processes at TIS and

	FROM	TO	Time Estimates	Comment
				loads into TDS.
6	MGS MR UHF Link Receiver	MER TDS	56 to 64 Minutes	Total latency without considering the SSR record/playback delay (possible 24 hours) described in the section 4.3

6. MSSS DATA DELIVERY INTERFACES SPECIFICATION

6.1 Media

1. MSSS shall retrieve MOC packets from MMO MGS TDS via virtual circuits.
2. MSSS shall put processed data on the MMO File server via file interfaces. MSSS shall produce the following three types of files for each relay session:

   i) MER Relay data (MER-1 and MER-2)
   ii) MR Summary data
   iii) HKTM Data

6.2 File Naming Convention

1. The MER-1 data file name shall be in the following format:

   MER1yyyydddabb.vvv

   where

   yyyy is the year
   ddd is the day of the year
   a is the UHF pass # of the day start at 1
   bb set to 01
   vvv is the version of the file (set to 001 for immediate delivery and 002 for post DSN pass delivery).

2. The MER-2 data file name shall be in the following format:

   MER2yyyydddabb.vvv

   where

   yyyy is the year
   ddd is the day of the year
   a is the UHF pass # of the day start at 1
   bb set to 01
   vvv is the version of the file (set to 001 for immediate delivery and 002 for post DSN pass delivery).

3. The MR Summary Data file name shall be in the following format:

    MR yyyydddabb.vvv

    where

    yyyy is the year
    ddd is the day of the year
    a is the UHF pass # of the day start at 1
    bb set to 01
    vvv is the version of the file (set to 001 for immediate delivery and 002 for post DSN pass delivery).

4. The HKTM Data file name shall be in the following format:

    HKTM yyyydddabb.vvv

    where

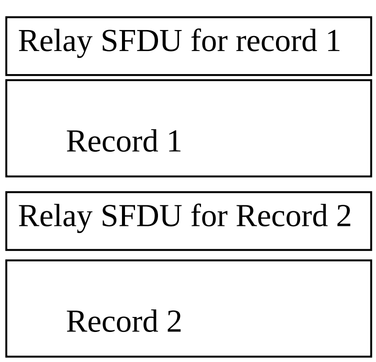
    yyyy is the year
    ddd is the day of the year
    a is the UHF pass # of the day start at 1
    bb set to 01
    vvv is the version of the file a (set to 001 for immediate delivery and 002 for post DSN pass delivery).

6.3 File Formats and file sizes

1) MER-1 and MER-2 data

Each data file shall contain one relay session worth of data which were transmitted from the MER.

The file shall contain records of variable size, each corresponding to a MOC packet, which contains relay data. Each record shall have the Relay SFDU header prepended. See the following diagram for example.



The Relay SFDU is composed of the following sub groups:

1.	Primary Label	20 bytes
2.	Aggregate Label	4 bytes
3.	Primary Header	8 bytes
4.	Secondary Header	76 bytes
5.	Data CHDO	4 bytes
		112 bytes

The format and value of the **Primary Label** are defined as follows:

```
   |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
 0 |                                                               |
   |                        authority_id                           |
 2 |                                                               |
   |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
 4 |         version_id            |           class_id            |
   |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
 6 |                             spare                             |
   |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
 8 |                                                               |
   |-                           ddp_id                             |
10 |                                                               |
   |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
12 |                                                               |
   |--                           spare                             |
14 |                                                               |
   |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
16 |                                                               |
   |--                        block_length                         |
18 |                                                               |
   |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
20 |
```

Byte Offset	Field Id	Description
0-3	authority_id	Constant, Value=0x4e4a504c (“NJPL”)
4	version_id	Constant, Value=0x32
5	class_id	Constant, Value=0x49 (“I”)

6-7	Spare.	Constant, Value=0x3030
8-11	ddp_id	Constant, Value=0x5a343536 ("Z456" – MER GIF TF.)
12-15	Spare	Constant, Value=0x0
16-19	block_length	block_length refers to the number of bytes of the current SFDU record MINUS the Primary Label, i.e. block_length = 92 + data_chdo_length

The format and value of **Aggregate Label** are defined as follows:

```
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  0 |                           chdo_type                           |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  2 |                          chdo_length                          |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
```

Byte Offset	Field Id	Description
0-1	chdo_type	Constant, Value=0x01
2-3	chdo_length	Constant, Value=0x54

The format and contents of the **Primary Header** are defined as follows:

(structure primary_hdr)

```
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  0 |                           chdo_type                           |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  2 |                          chdo_length                          |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  4 |           major               |             minor             |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  6 |         mission_id            |             format            |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
```

Byte
Offset | Field Id | Description

0-1	chdo_type	Telemetry primary header CHDO type code. (Value = 0x0002).
2-3	chdo_length	Length of CHDO value field (remainder of header). (Value = 0x0004).
4	major	Constant, Value=0x01.
5	minor	Constant, Value=0x05.
6	mission_id	Constant, Value=0x1a (= 26 for MER)
.		
7	format	Constant, Value=0x01

The format and value of the **secondary header** are defined as follows:

```
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  0 |                    secondary_chdo_type                         |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  2 |                   seconday_chdo_length                         |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  4 |                                                               |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  6 |            scft_id             |          data_source          |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  8 |                                                            H  |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
 10 |                              ert                              |
    |---                                                         ---|
 12 |                                                               |
    |---                                                         ---|
 14 |                                                               |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
 16 |                                                               |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
 18 |                       dsn_record_seq                          |
    |---                                                         ---|
 20 |                                                               |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
 22 |                                                               |
    |                                                               |
 24 |                                                               |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
 26 |                   actual_data_length                          |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
 28 |                                                               |
    |                                                               |
 30 |                                                               |
    |                                                               |
 32 |                                                               |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
 34 |                                                               |
    |                          bit_rate                             |
 36 |                                                               |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
 38 |                         Relay SCID                            |
```

```
   |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
40 |                                                               |
   |                                                               |
42 |                                                               |
   |                                                               |
44 |                                                               |
   |                                                               |
46 |                                                               |
   |                                                               |
48 |                                                               |
   |                                                               |
50 |                                                               |
   |                                                               |
52 |                                                               |
   |                                                               |
54 |                                                               |
   |                                                               |
56 |                                                               |
   |                                                               |
58 |                                                               |
   |                                                               |
60 |                                                               |
   |                                                               |
62 |                                                               |
   |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
64 |                              rct                              |
   |---                                                         ---|
66 |                                                               |
   |---                                                         ---|
68 |                                                               |
   |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
70 |                                                               |
   |                                                               |
72 |                                                               |
   |                                                               |
74 |                                                               |
   |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
```

Byte Offset	Field ID	Value
0 - 1	secondary_chdo_type	Value is fixed at 0x51
2 - 3	secondary_chdo_length	Value is fixed at 0x48
4 - 5	SPARE	Zero-filled
6	scft_id	0xfd for MER1 and 0xfe for MER2
7	data_source	Value is 0xC8.
9	H = Relay Flag	Set byte 9 to value = 1
10 - 15	ERT	ERT of the first MOC packet composed of this record.

16 - 17	SPARE	Value is fixed zero.
18 - 21	dsn_record_seq	The process that creates the MR SFDU will be expected to number all the SFDUs it creates sequentially from 0 through 65535 -- this count will be placed in the dsn_record_seq field. After 65535 the number will rollover to 0 and the sequence will begin again. If consecutive records have a gap in their sequence count TIS will generate an anomaly. Note that this is a 4-byte field where the

counter only uses 2 bytes. This is OK from a TC&DM perspective, as long as the byte 18 and 19 are zero-filled.

22 - 25	SPARE	Zero-filled
26 - 27	actual_data_length	This field is the actual data length in number of bits, i.e. the number of valid bits in the data CHDO data field (it doesn't include pad used to create an even byte data chdo).
28 - 33	SPARE	Zero-filled
34 - 37	bit_rate	Bit rate of the first MOC packet composed of this record. This field is stored as an IEEE 32 bit floating point number.
38 – 39	Relay SCID	Set to 0x0 for byte 38 and 0x5E for byte 39 (MGS).
40 - 63	SPARE	Zero-filled
64 - 69	RCT	Record Creation Time. The current system time when MOC generate the record. The format is described under TIME_FORMAT below.
70 - 75	SPARE	Zero-filled

The format and value of **Data CHDO** are defined as follows:

```
|---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
```

```
  0 |                        data_chdo_type                         |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  2 |                       data_chdo_length                        |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
```

Byte Offset	Field ID	Value
0 - 1	data_chdo_type	Value is fixed at 0x000a
2 - 3	data_chdo_length	Length of chdo data field in bytes starting at the byte following this field. This value will always be an even number of bytes (requiring the data field to be padded at the end if the valid data is not on an even byte boundary).

TIME FORMAT

In an SFDU, a time field, such as ERT or RCT, will be in the following 48 bit format:

```
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  0 |                             days                              |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
  2 |                                                               |
    |--                       milliseconds                        --|
  4 |                                                               |
    |---+---+---+---+---+---+---+---+---+---+---+---+---+---+---+---|
```

Byte Offset	Field ID	Value
0 - 1	days	Days since January 1, 1958, starting with 0.
2 - 5	milliseconds	Milliseconds of the current day.

2.) The MR Summary Data

Ancillary Record #1
Ancillary Record #2
Ancillary Record #3
ooo
Ancillary Record #n

The Ancillary Record, which corresponds to a BTTS, has the following contents and, and the format of the record is the following:

1.	DSN Station ID	1 byte	DSN station Id of the first MOC packet composed of this record.
2.	MGS ERT	20 bytes	MGS ERT of the first MOC packet of a BTTS. Format = ASCII: yyyy/dd-hh:mm:ss.sss
3.	MGS RCT	20 bytes	MGS RCT of the first MOC packet of a BTTS. Format = ASCII: yyyy/dd-hh:mm:ss.sss
4.	MGS SCLK	20 bytes	MGS SCLK of the first MOC packet of a BTTS. Format = ASCII: yyyy/dd-hh:mm:ss.sss
5.	Gap Summary Flag	2 bytes	General quality flag of each relay data BTTS. 1: without MOC gap in the BTTS 2: with MOC gap in the BTTS

3.) The HKTM Data

HKTM Record #1
HKTM Record #2
HKTM Record #3
o o o
HKTM Record #n

7. MSSS OPERATIONS INTERFACES SPECIFICATION

1) Data retrieval frequency

   a) MSSS shall retrieve data from the MGS TDS in real time when MGS is tracked by DSN
   b) MSSS shall retrieve besting enhanced data from the MGS TDS post DSN tracking pass.

2) Data Delivery Frequency

   a) MSSS shall return the MER data file within [5] minutes after each MER data file is generated.

b) MSSS shall return the relay data files within [1] hour after the besting enhanced data is available.

3) Data Delivery Location

MSSS shall return data to the Distributed Object Manager (DOM) at JPL with the following keywords:

MISSION_ID = 5
SPACECRAFT_ID = 94
MISSION_ACRONYM = MGS
DATA_SET_ID = HKTM_MR

MGS project shall authorize the MER data operations for read access of the HKTM_MR data set.

8. MGS Operations Support

8.1. MGS Phasing

In order for MGS to be in a position to support EDL, it may require MGS to conduct orbit phasing so that EDL overflight is achieved for both MER-A and MER-B. Preliminary estimates indicate a delta V of up to 4 m/sec may be required to accommodate both rovers. Phasing for MER-A EDL will likely begin with an orbit synchronization maneuver (OSM) at three months prior to EDL, followed by an OSM approximately two months before EDL, and a final “cleanup” OSM at about two to three weeks prior to EDL. Phasing for MER-B EDL will begin following the MER-A EDL, followed by a final “cleanup” OSM approximately one week prior to MER B EDL. Phasing will place MGS at the highest elevation angle possible, with respect to navigation uncertainty and the limitations inherent in in-plane, time phasing OSMs only, at a time centered between MER bridle deploy and bridle cut (from the MER landing site perspective).

1. MGS Orbit Synchronization Maneuvers (OSMs) For MER-A EDL.

a) At 3 months before MER EDL, an initial MGS OSM shall be executed such that MGS shall be "overhead" or nearly so to receive telemetry during MER "bridle deploy to bridle cut" during the EDL phase.

b) An OSM shall be available approximately 2 months before MER-A EDL in order to be prepared for an unexpected MGS small force environment.

c) A final OSM at 2-3 weeks before EDL shall be executed to finalize the MGS synchronization.

d) No inclination or out-of-plane component of the OSM shall be required in order to minimize the MGS delta-velocity required.

e) Based on our current analysis, the expected timing error (or down-track position component) after 2 weeks of the final OSM varies from -10 to +10 seconds, at an orbital speed of 3.3 km/sec, this amounts to +/- 33 km of down-track position error. This assumes the current state of MGS AMDs (angular momentun desaturations) and does not account for maneuver execution errors. However, note that down-track or timing errors as large as +/-30 seconds after two weeks of prediction can occur in anomalous situations. Errors in the cross-track component of the MGS position are being analyzed.

f) The nominal date for the MER-A EDL shall occur on 01/04/2004.

2. In order for MGS Navigation to plan for this implementation, the following information is required.

a) MER-A and MER-B touchdown times and site coordinates (in a Mars fixed/rotating coordinate system whose prime meridian and Mars reference constants need to be reviewed) along with three sigma uncertainties in these quantities. Preliminary estimates should be provided now with updates in April 2003. The final set of values shall be provided at MER-A EDL minus nine months (Table 8-1, item 1).

b) An ephemeris of the spacecraft's motion during the EDL phase with the epochs of the bridle deploy and cut. The coordinate systems are Mars centered, inertial with respect to the Mars mean equator of date and the IAU vector (earth mean equator) of epoch J2000 and the above Mars fixed/rotating coordinate system (Table 8-1, item 2).

c) Most likely, MGS will not be at the "maximum elevation with respect to the MER landing site at the time [centered between the bridle deploy and bridle cut]" because of the down-track and cross-track errors previously mentioned. The MER project shall provide acceptable tolerances in these quantities that will still accomplish EDL relay objectives (Table 8-1, item 3).

3. MGS Orbit Synchronization Maneuvers (OSMs) For MER-B EDL

a) The initial MGS OSM for the support of the MER-B EDL may be executed immediately after the MER-A EDL. However, the placement of this maneuver should neither jeopardize the playback of the MER-A EDL data, nor adversely impact the ability of MGS to provide relay support through the early morning pass on sol 3 following the MER-A landing. . If the OSM for MER-B EDL is executed after the sol 3 of MER-A landing, this could cause the 4 m/s delta-velocity allocation to be exceeded and will require the approval of the MGS Project Manager.

b) Because of the short interval between the MER-A and MER-B EDLs, a contingency OSM may not be required. Nevertheless, a placeholder OSM should be planned for at MER-B EDL minus two weeks.

c) A final OSM at one week before MER-B EDL shall be executed to finalize the MGS synchronization.

d) The MER-B EDL shall occur on 01/25/2004 (21 days after MER-A EDL); this is an update to the previous MER-B EDL plan of 02/08/2004.

4. MER Post-Landing Surface Operation and UHF Relay with MGS.

a) More detail is necessary to understand the MER requirements for the utilization of MGS as a relay satellite; for example, the duration and frequency of the contact periods, their timeliness and the necessary MGS over-flight geometry and tolerances. The process of the detail requirements and utilization coordination between MER and MGS is described in Section 8.4.2

5. Additional Information

a) The format for the transfer of information are the current navigation files (i.e. SPK, OPTG, and LOPTG). No new file interface shall be required.

b) Based on a previous MER design study, MGS has allocated 4 m/s delta-velocity to accomplish these phasing maneuvers. Within the next several months, MGS navigation shall perform a simulation to analyze and verify this synchronization plan.

c) MGS is not planning to reconstruct any MER trajectory or landing site – should this be necessary, it will be done by MER personnel.

d) If MGS should experience a failure with its reaction wheels, which substantially changes the spacecraft's small forces environment, this plan may need to be reviewed and revised.

e) Note that MGS shall transition from an operational configuration called "beta supplement" to "nominal operations" on 09/13/03 (estimated) or MER-A EDL minus 3.5 months. Usually there is a change in the spacecraft's small force environment during this transition.

The following table summarizes the MGS Navigation required Information from MER.

Table 8-1

MGS REQUIRED INFORMATION	RESPONSIBLE PERSON	DUE DATE
MER-A and MER-B EDL touchdown times and coordinates, with three-sigma uncertainties, in a Mars fixed coordinate system. Additional post-MER launch updates may be required.	Phil Knocke	Initial: Feb 2002 Update: May 2002, Sept. 2002 Final: April 2003 Post Launch: one month after each launch.
MER spacecraft EDL ephemeris, in two coordinate frames, with epochs of events, especially the bridle deploy and cut events.	Phil Knocke	Initial: May 2002 Final: April 2003 Post Launch: one month after each launch.
MER shall provide tolerances for MGS to be at the "maximum elevation" and at the time to be specified for EDL. These tolerances shall also be provided for MER surface relay operations.	Andrea Barbieri	Initial: May 2002 Final: After 2003 Post Launch: one month after each launch
For the MER surface operations/relay phase, provide the times, duration and frequency of MGS contact/relay periods.	Bill Bensler	Initial: Sept. 2002 Final: After 2003 Post Launch: one month after each launch

8.2. MGS Planning and Sequencing Operations

MGS shall perform the planning and sequencing of the MGS MR, MOC, PDS and other spacecraft subsystems as related to MR operations to capture MER data and return it to Earth.

8.3 EDL Operations

The data transmitted from MER to MGS during MER EDL shall be treated as the highest priority data by MGS. It shall be transmitted to Earth at the earliest possible DSN pass during or after the EDL. The recorded EDL data shall be played back repeatedly in the subsequent DSN passes for up to five times until the complete reception of EDL data.

8.3.1 Planning and coordination meetings

A series of planning and coordination meetings will be held in the months leading up to the MER-A and MER-B landings. At MER-A EDL – 8 months, the MER Mission Planning Team will deliver information to the MGS program that will allow the MGS operations team to design the initial MGS phasing OSM. The provided touchdown times and site coordinates shall serve as a reference target for all three potential OSMs leading up to MER-A EDL.

A series of meetings between the MER MPT and the MGS operations team will take place several weeks before each rover landing with the objective of verifying the DSN coverage for MER and MGS during EDL and finalizing the MGS playback schedule for the collected UHF data. In addition, the MER MPT shall provide the MGS operations team with the UTC time at which MGS will be at the maximum apparent elevation as viewed from the rover during EDL. This information will be derived from an Orbit Propagation and Timing Geometry (OPTG) file produced by the [MMO/MER] Navigation team, and any analysis and simulation performed by the MER Spacecraft and MPT teams. The time shall be used in defining the desired times of the sequenced MGS MOC, MR, and PDS commands.

8.3.2 Sequencing Operations

In order for MGS to be ready for EDL, a mini-sequence will be loaded several days prior to each EDL event; the sequence will control the MR transceiver and MGS spacecraft during relay operations. The MOC buffer shall be cleared prior to EDL. The MOC will also be commanded prior to EDL to enable the capture of the MR data. The period of data capture will begin with the 10 minute interval centered on the time period [between the bridle deployment and the bridle cut] and will continue after the MER has landed. In this sequence, the MR transceiver on MGS shall be in the EDL communications mode (Mode 1); and configured as described in Section 2.2.2.

In the event that MGS will receive real-time DSN coverage during the MER EDLs, the PDS will be configured via sequenced commands to [S&E1-RT] mode for real-time downlink of the received MER UHF EDL data as well as recording the EDL data to the SSR for later playback. If MGS coverage will not occur until the rise of the next visible station after a MER EDL event, the PDS will be configured via sequenced commands to [S&E1] mode in order to store the MOC data on the SSR for later playback at the earliest opportunity with the highest priority. This option also requires that separate commands be sequenced to initiate the playback of the MER EDL data to Earth.

8.3.3 Data Delivery (MSSS) Operation

During EDL, MSSS shall perform operations in real-time during the DSN pass to downlink the MER EDL data, and deliver the extracted data as soon as possible. The MOC buffer status during the EDL shall also be reported to the MER operations team as soon as it becomes available.

8.3.4 Feedback to MGS

MER project should provide feedback to MGS project for the complete reception of EDL data.

8.4 Surface Operations

For surface operations, MGS shall support up to two communication sessions per sol per rover during the 90 sol primary mission of each rover (from the Post Landing Through

Egress to the End of Mission for approximately 120 days). Similar support is expected for any subsequent extensions to the MER mission.

8.4.1. Post Landing Through Egress (PLTE)

The UHF relay during the first several sols after landing is a special check out period. The relay data requires quick turn around during this period in order to assess the UHF radio and link performance. A series of meetings between the MER MPT and the MGS operations team will take place several weeks before each rover landing and after the EDL coordination meetings, with the objective of verifying the DSN coverage for MER and MGS during the PLTE and finalizing the MGS playback schedule for the collected UHF data.

8.4.2 Support MER Strategic Planning

MER strategic planning occurs on a weekly basis. Each week the MER Mission Planning Team will develop a strategic plan containing 14 sols' worth of activities. The plan being developed in a given week will go into effect the following week; the final 7 sols' worth of activities from the previously developed plan will be superceded by the new plan.

As part of the 14-sol strategic plan, a two-week relay contact plan will be generated and delivered to both supporting orbiter programs. This relay contact plan will include a list of the selected MGS passes' start and stop times as well as the expected quantity of transmitted UHF data that a rover will produce on a given pass. This information, delivered in the form of an APGEN planning file (APF) shall serve as the basis for building the required MGS UHF relay sequences.

To provide a means of exchanging the required planning information, an MGS representative shall attend a weekly MMO Mission Planning meeting. The activities at this meeting will include identifying and selecting specific orbiter passes for each of the involved surface elements, determining the final DSN allocations including MSPA coverage opportunities, and predicting the generated data volumes for each of the selected passes. Representatives from MER, MGS, Mars Odyssey, Beagle, MMO, and the DSN are expected to attend.

8.4.3 Sequence Operations

The MGS sequencing team shall build and radiate MGS UHF relay sequences twice a week. Based on inputs from the MER relay contact plan (APF), the MGS sequencing team will produce a spacecraft activity sequence file (SASF) containing the necessary MR, MOC, and PDS commands needed to configure MGS to receive MER UHF transmissions during the designated passes. The SASF containing the relay commands will be fed into SEQGEN and the ultimately be used in constructing the CMD_DSN files that are radiated to MGS. In addition to building the UHF relay configuration sequences, MGS shall also build corresponding X-band telecom sequences that specify the MGS data playback schedule. A report containing the expected relay downlink will then be delivered to MER on a weekly basis.

8.4.4 Data Delivery Operation

During the surface relay operations, the MSSS shall automate the relay data processing to the extent practical, and deliver the relay data described in Section 7. MSSS shall provide contact phone number(s) for technical support to the MER project in case of problems. The initial response time from MSSS shall be 2 hours or less, 24 hours a day, 7 days a week.

9. MGS Test Support

9.1 Verification

The verification approach is partitioned into several separate activities. MER will supply a verification plan for all necessary verification and validation tests. MGS will make available data, software tools and information pertinent to the MER-MGS UHF link as requested (e.g. MGS antenna pattern descriptions). In addition, MGS will supply appropriate hardware and personnel to perform the various tests. In particular, the availability of a flight-like MGS test set is required between [February and December of 2002], to support ATLO and UHF compatibility tests.

Though approximate time frames are described with each type of test, they are notional and may be modified by MER as necessary.

9.2 General Tests

9.2.1 Preliminary Radio Frequency Compatibility Test (completed).

MER will be responsible for the demonstration of the radio frequency compatibility between the MGS radios and the MER UHF radio. MGS will provide a test unit that is functionally equivalent to the MGS telecommunication capability.

This test was conducted in May 2001 using the MER Engineering Development Unit (EDU) with the MGS test unit.

9.2.2 Test of MGS Relay Data Service

The following tests are on orbit tests of the MGS relay with the SRI 46-meter antenna at Stanford University. These tests are planned to occur at the time of minimum Mars to Earth range for maximum signal strength.

MER will supply support to the creation of the test plan in order to ensure that the tests supply enough characterization of the MGS interface so that MER can verify the relay function.

MGS will supply the data from these tests to MER and MER will perform analyses that are necessary to demonstrate that the capability of the one-way mode will be adequate to meet EDL requirements.

9.2.3 Stanford Test June 2001 (completed)

This test successfully demonstrated the MGS' capability in one-way mode to support the EDL relay. The two-way mode cannot be performed due to the long propagation delay. Details of this test and its results were described in the MER Project MGS Mars Relay On-Orbit UHF Test Description.

9.2.4 Stanford Test September 2003

It is a goal to perform the Stanford Test in 2003. An MCR is required by the MGS project by September 2002 to plan for this test. If approved, .MER and MGS will jointly perform the one-way mode EDL relay testing and analyses in the August/September 2003 time frame. The two-way mode cannot be performed due to the long propagation delay.

9.3 ATLO and Testbed Tests

To support the verification and validation efforts, the following two tests are expected to be conducted around the same time as MER-Odyssey UHF compatibility test at ATLO. Both tests are expected to require an MGS simulator or an MGS relay test set.

9.3.1 Radio Compatibility Test

This test will check out the MR radio's compatibility with MER-1 and MER-2 UHF flight units in the MER ATLO. The MER-1 test is scheduled for March 2002 and MER-2 test is scheduled for May 2002. The actual testing date may vary. MER will plan, execute, and analyze the tests. MGS will provide a test engineer to support both MGS compatibility tests.

9.3.2 End-to-end Data Flow Test

The MER project will perform an end-to-end test to validate relay data flow and handling compatibility between MER-1, MER-2 spacecrafts and MGS. MGS and MER ground data systems shall be prepared to support up to [5] end-to-end data flow tests in the [September through December 2002] time frame using the MER flight system test bed. This test will require data processing support by MSSS.

9.4 ORT

The ORTs to verify MER operational interfaces with the MGS (including Malin Space Science System) are the following:

- ORT6B-S (Nominal Surface Operations)
  - MER-B ORT with MGS relay
- ORT7A-A/E/S* (Approach/EDL/Surface—with Anomalies)
  - MER-A ORT with MGS EDL relay
  - This MER ORT is timed to coincide and interact with MGS/Odyssey/ Stanford-In-flight UHF tests where MER telemetry will be sent from Stanford to Odyssey and MGS (In-flight).
- Parallel ORTs 10A-S/10B-S (both Nominal Surface Operations)
  - Parallel MER-A/MER-B ORTs with both MGS and Odyssey relays

During ORT7A-A/E/S*, MER-A EDL relay operations will be timed to coincide with Stanford UHF-relay in-flight tests involving the MGS flight vehicle.

The other ORTs shown above will involve the MGS Project supporting MER UHF-relay operations, building the MGS flight-vehicle command sequences, and processing and delivering MER UHF telemetry through the operational MGS-to-MER ground interfaces at JPL.

APPENDIX A: ACRONYMS LIST

APID	Application Packet ID
ARQ	Automatic Repeat Request
ASM	Attached Synchronization Marker
BER	Bit Error Rate
BTTS	Balloon Telemetry Time Slot
CCSDS	Consultative Committee for Space Data Systems
CRC	Cyclic Redundancy Code
CW	Continuous Wave
DOM	Distributed Object Manager
DSN	Deep Space Network
EDAC	Error Detection and Correction
EDL	Entry-Descent-Landing
FECW	Frame Error Control Word
FER	Frame Error Rate
GDS	Ground Data System
HKTM	Housekeeping Telemetry
MBR	Mars Balloon Relay
MCR	Mission Change Request
MER	Mars Exploration Rover
MGS	Mars Global Surveyor
MOC	Mars Orbiter Camera
MSSS	Malin Space Science System
PSK	Phase Shift Keying
QoS	Quality of Service
RHCP	Right Hand Circular Polarization
RS	Reed Solomon
SCID	Spacecraft ID
TBC	To Be Confirmed
TDS	Telemetry Data Distribution
TIS	Telemetry Input Subsystem
UHF	Ultra High Frequency
VC	Virtual Channel
MPT	MER Mission Planning Team
OSM	MGS Orbit Synchronization Maneuver
PDS	MGS Payload Data System
PLTE	Post Landing thru Egress